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Fabrication of a Composite Airfoil With a Large Scale Twist Capability

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Fabrication of a Composite Airfoil With a Large Scale Twist Capability

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Abstract

This technical note describes the fabrication of a composite airfoil shaped part that could twist easily about its long axis, but would not flex easily. This part was fabricated using a polyurethane resin matrix glass reinforced composite material that performed satisfactorily in wind tunnel tests. Possibilities for scale-up to very large parts are described.

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1. Introduction

This technical note describes the fabrication of a composite airfoil shaped part that could twist easily about its long axis, but would not flex easily. This was one of the significant challenges of a Federated Laboratory project to demonstrate the potential utility of such an airfoil as a windmill blade. Once the blade reaches a certain speed, the power generation efficiency of the blade can be improved if the blade is twisted around its long axis. The twist was introduced by applying a current to a shape-memory alloy wire wrapped around the part. The airfoil shaped part was fabricated using a glass fabric reinforced polyurethane elastomer matrix composite at a minimal cost. The materials selection, composite airfoil fabrication, and possibilities for scale-up to very large parts are described in this note. The performance of the airfoil was satisfactory, and twists well in excess of the needed 7 degrees were possible. Details of its modeled and measured performance will be presented elsewhere.

2. Materials Selection

The elastomer selected for this project was Adiprene L-100 polyurethane cured with CATUR 21. Both components were manufactured by and obtained from Uniroyal Chemical.* In previous U.S. Army Research Laboratory (ARL) work [1], this polyether-based polyurethane exhibited a hardness of Shore-A 85, somewhat harder than an automobile tire (Shore-A 75) and softer than a typewriter roller (Shore-A 90). Nearly all of the toluene-diisocyanate it contains is chemically bound, which makes it relatively safe to handle. Its most attractive feature is a fairly long working life, limited mainly by hydrolysis of the resin by moisture in the air. It is best worked at a temperature of about 140 degrees F. At this temperature, its viscosity drops to a low of about 2200 centipoise, which is low enough for some resin transfer molding processes. It cures rapidly at temperatures above 212 degrees F. Its glass transition temperature is below the −60 degree F limit of the differential scanning calorimeter used for this test. The resin has been used on other ARL projects that required a semi-flexible composite. Its selection followed an extensive search for appropriate thermoset resins through vendor contacts, in-house tests, and technical discussions with other DOD personnel.

* Uniroyal Chemical Co., Inc., World Headquarters, Middlebury, CT 06749.

The glass fabric used for the project was a 24 oz per square yard 5 × 5 S-2 glass woven roving. This fabric has been used extensively for ARL armor work for at least the past 15 years. The sizing is the standard epoxy compatible/polyester semicompatible type 463 sizing.* Apparently, no commercially available sizing has been specifically developed for polyurethane resins [2]. This fabric typically contributes 25 mil per ply to the thickness of a composite. Samples of such composites cut along a weave direction (0 or 90 degrees) will twist relatively easily, but will not flex well. In comparison, samples cut at 45 degrees will flex easily, but will resist twisting.

3. Airfoil Fabrication Details

The first major requirement for fabricating the airfoil was a mandrel of an appropriate size and shape over which fabrics could be draped or glass filaments wound. An approximately 5-ft-long section of a rotor blade for the UH-58 "Huey" helicopter was available for experimentation at ARL. This blade section is about 13-in wide and has a maximum width of 1.5 in. Although this is not an ideal airfoil shape, it was determined to be a sufficiently good approximation to start this project. The rotor blade used in the fabrication process is shown in Figure 1.

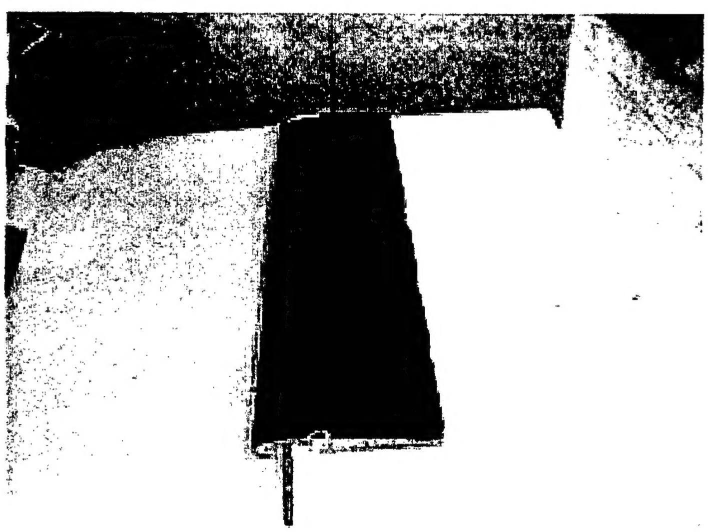

Figure 1. The helicopter rotor blade section used as a mandrel for the airfoil fabrication process.

* Advanced Glassfiber Yarns, Aken, SC.

The airfoil blanks were fabricated using a vacuum-assisted resin transfer molding process known as SCRIMP (Seeman's Composite Resin Infusion Molding Process [3]). This process is illustrated in Figures 2 and 3. First, the tool (in this case the rotor blade) was coated with five coats of Frekote 700 mold release.* Next, a layer of nonporous Teflon-coated glass release film (Richmond 200TFNP)† was then laid over the rotor blade and taped in place. Two plies of glass fabric, 34 in wide × 50 in long, were placed over the release fabric with the 90 degree direction along the long axis of the rotor. A ply of Richmond A8888 open weave polyamide release fabric† was laid over the glass. The edges of these fabrics were also taped to the mandrel. A layer of transfer medium, such as the 40–50% shade dark-green plastic awningscreen,† also shown in Figure 2, is then placed over the part. This transfer medium is cut about 8 in shorter than the 34 in length of the part. This forces the resin to flow down through the part and thus completely fill out the part before it reaches the vacuum line.

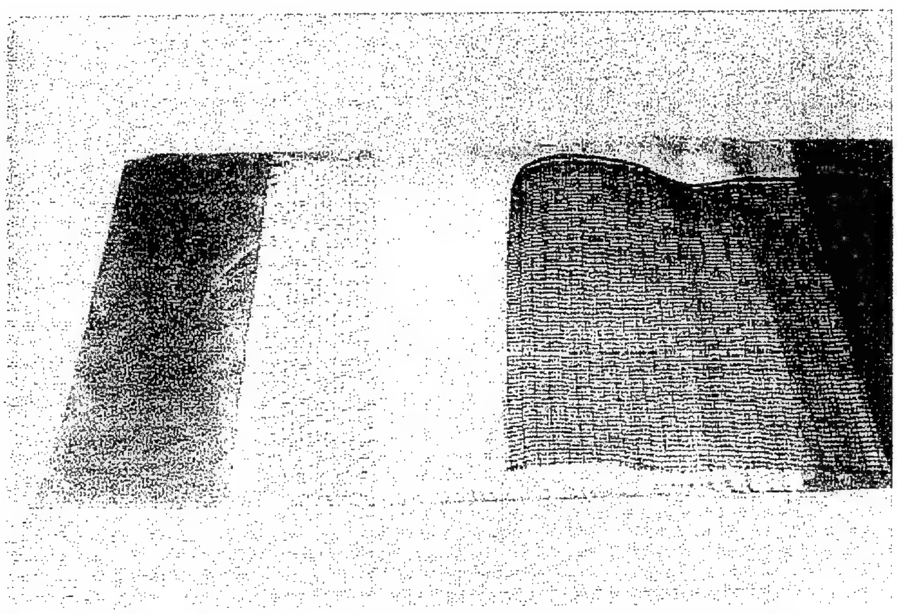

Figure 2. The SCRIMP process. Successive layers of Teflon-coated glass release fabric (brown layer at left of picture), fiberglass fabric (white layer) to make the part, A8888 polyamide release fabric (light green fabric) and transfer medium (dark green fabric) were applied over the mandrel.

* The Dexter Coporation, Frekote Products, 1 Seabrook Dr., Seabrook, NH 03874.

† Northern Fiberglass Sales, Inc., PO Box 2010, Hampton, NH 03483-5098.

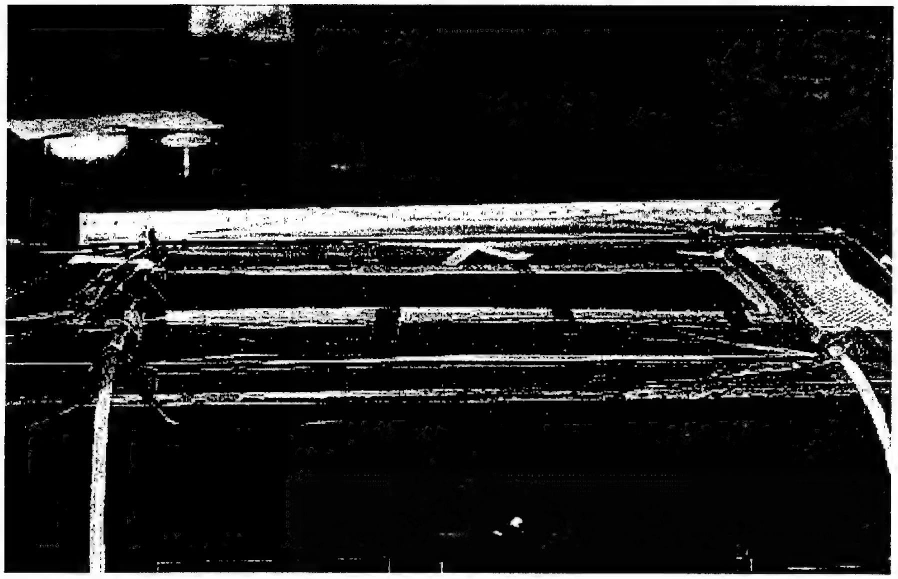

Figure 3. A SCRIMP panel ready for infusion. The fill line is at the left, and the vacuum line is at the right. A black transfer medium was used in this case.

The transfer medium is also cut about 1 in smaller than the part on the two perpendicular sides. This prevents the development of a low impedance path (a "race track") along the sides of the part. A vacuum line, made from stretched 0.5-in OD Panduit plastic electrical spiral wrapping (part number T62F)* wrapped in a layer of 8.8-oz E or S-2 glass fabric, is placed at the end of the fabrics. A feed line in the form of a 0.75–in-diameter, 5-turn per inch steel spring was then placed on the leading edge of the rotor blade. Several layers of the transfer medium were used to separate it from the part. The entire assembly was then vacuum bagged (0.002-in-thick CAPRAN 512 bagging film† is the preferred material). Figure 3 shows a flat part vacuum bagged and ready for resin infusion. The fabrics were then infused with resin in a 140 degrees F walk-in oven. This process took about 1.5 hr. Once the resin transfer was complete, the blank was cured at 250 degrees F, debagged, and trimmed to size.

The airfoil blanks made in this manner had an open seam on the trailing edge of the parts. On the first part made, this was sealed at the 13-in width along a 1-in-wide flat. The Adiprene resin was used for the bonding since it results in a very strong bond—lap-shear samples prepared in this manner failed when the resin pulled off the glass [4]. The finished airfoil is shown in Figure 4.

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* Northern Fiberglass Sales, Inc., PO Box 2010, Hampton, NH.

† Graybar Electric Company, New Castle, DE.

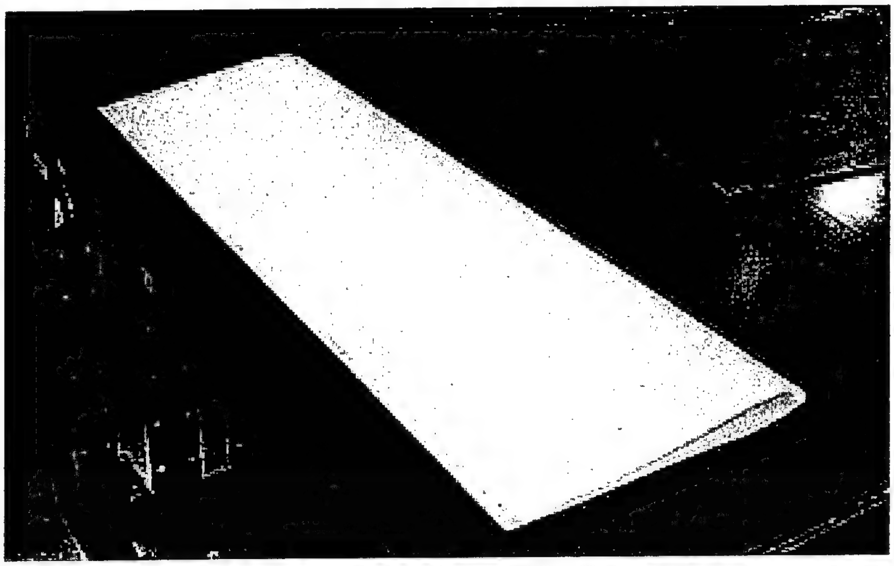

Figure 4. The first airfoil fabricated.

Ideal airfoils are somewhat fatter and symmetric. The second airfoil part was trimmed to a 9-in width; two 50-mil-thick, 1/4-in-wide strips of flat Adiprene-based composite stock were bonded in between the top and bottom of the airfoil part to make a somewhat more desirable airfoil. Two views of this airfoil are shown in Figures 5 and 6.

4. Scale-Up Possibilities

The SCRIMP process employed in this effort was excellent for fabricating the narrow, thin airfoils that were made. It would be difficult to fabricate considerably larger and thicker airfoils by this process, since it is very slow with this viscous resin. However, a process known as FASTRAC (fast remotely activated channeling) [5, 6], newly developed at ARL, would be suitable for full-size windmill vanes. The ultimate thickness of parts that can be made by this process with the Adiprene resin has not been established, but may be as much as an inch. The vanes could be made thicker if necessary by repeated applications of the process. Since a temperature of 250 degrees F is all that is required to cure the resin, an oven of adequate size could easily be built around the part. The fabrics could be stitched at the trailing edge of the mandrel, eliminating the bonding step. Success in removing filament wound tubes made with the Adiprene resin indicates that the airfoils could be slid off the end of the mandrel without the aid of the open seam used in the current project.

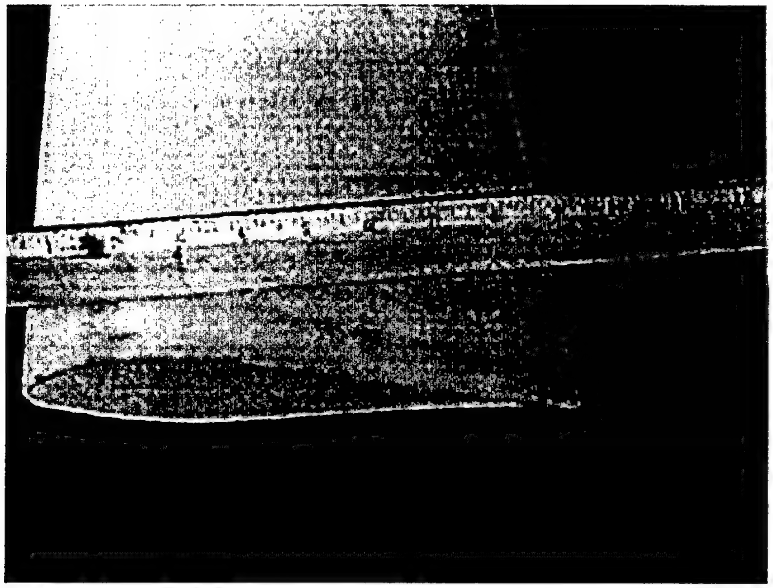

Figure 5. The second airfoil fabricated.

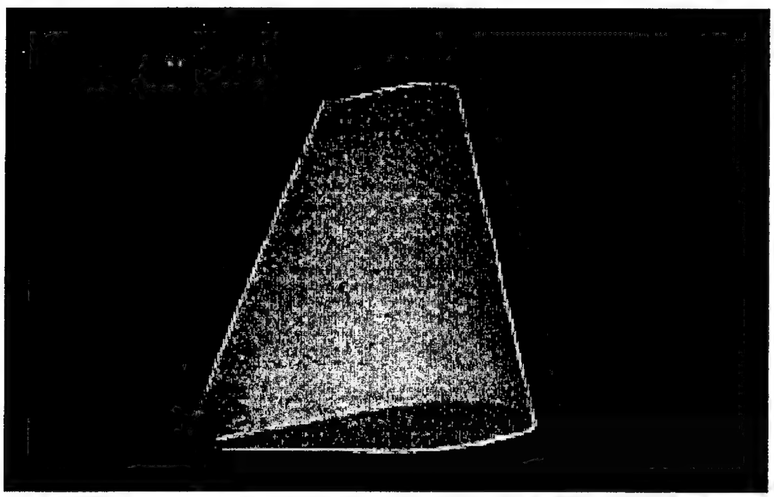

Figure 6. Another view of the second airfoil fabricated.

Depending on the size and shape of the airfoil, it may also be possible to braid the glass over the mandrel rather than using fabrics. This braided structure would then be infused with resin by a process such as FASTRAC. A stitched or stapled preform that could be similarly infused with resin may be a viable alternative to the braided structure. Filament winding would also be a possibility, provided that the part is not too large.

5. Conclusions

The successful fabrication of a polyurethane composite airfoil for use as a windmill blade prototype was demonstrated on a 42-in-long part. Fabrication of a full size windmill blade would clearly require some developmental work, but there is ample reason to expect eventual success.

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13. ABSTRACT*(Maximum 200 words)*

This technical note describes the fabrication of a composite airfoil shaped part that could twist easily about its long axis, but would not flex easily. This part was fabricated using a polyurethane resin matrix glass reinforced composite material that performed satisfactorily in wind tunnel tests. Possibilities for scale-up to very large parts are described.

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